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PROPAGATION MEASUREMENTS FOR AN AUSTRALIAN LAND MOBILE-SATELLITE SYSTEM

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ABSTRACT

The Australian domestic satellite service provider Aussat Pty. Ltd. is planning to introduce Land Mobile-Satellite Services (LMSS) at L-band in 1991/92. This will be a new service for Australia and many technical details need resolution. Although it is known that attenuation due to roadside trees is significant it is not well quantified. This paper describes measurements of attenuation statistics using a helicopter and an instrumented van. Results are given for two different tree densities, for elevation angles of 30, 45, and 60 degrees and for frequencies of 893, 1550, and 2660 MHz. These results show that at 1550 MHz and 45 degrees elevation angle, attenuation values of 5.0 and 8.6 dB were exceeded 10% of the time for roadside tree densities of 35% and 85% respectively. Comparisons with other results based on measurements made in the Northern Hemisphere are made and show general agreement. The implication of the measured values on system design are discussed, and it is shown that, for Australia, an adaptive margin allocation scheme would require an average margin of approximately 5 dB.

INTRODUCTION

Domestic satellite communications in Australia are provided by 3 Ku-band satellites operated by Aussat Pty. Ltd., which is a company owned by the Australian federal government and Telecom Australia, the nation's telecommunications company. In 1991/92 Aussat will launch two new second generation satellites to replace those currently in service. Each of these satellites will include one L-band transponder (as well as a Ku-band communications payload) designed to provide a Land Mobile-Satellite Service (LMSS) for the Australian continent.

A LMSS will be a new service for Australia and the Telecom Research Laboratories is studying the various technical issues involved with such a system. The effects of propagation on the path between the mobile terminal and the satellite are a major concern and while there are a number of effects ranging from ionospheric scintillation to multipath, attenuation by roadside vegetation can be most significant (Vogel and Smith, 1985). For economic reasons satellite systems are designed with the minimum propagation margin consistent with desired performance objectives. The attenuation due to roadside vegetation must be properly quantified, and a number of measurements of attenuation statistics have been made in the northern hemisphere over

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the past few years (Butterworth, 1984; Vogel and Smith, 1985; and Goldhirsh and Vogel, 1987).

Telecom has also measured attenuation statistics for parts of Australia because the data available from these previous measurements was not directly applicable. Australia has its own unique flora with non-deciduous eucalyptus and acacia trees predominant alongside roads. Further, the frequency and elevation angle ranges of interest differed from those measured elsewhere. In any event, the data base for attenuation statistics is currently narrow and further measurements will contribute to the broadening of this base.

MEASUREMENT CONFIGURATION

The Australian continent covers just over 30 degrees of latitude and elevation angles to the Aussat satellites vary from approximately 30 to nearly 70 degrees with most of the continent over 45 degrees. The tree type varies from dense tropical rainforest to sparse stunted growth in areas of low rainfall. There are also vast treeless plains such as the Nullarbor plain (L. *nullus*, not any, *arbor*, tree) which has an area of over 16 million ha. When the measurement programme was planned, there was uncertainty on the appropriate frequency bands for LMSS and data were required at various frequencies to cover possible eventualities. Data were therefore desired on the effects of elevation angle, frequency and tree type on the attenuation statistics.

A helicopter was chosen as the platform for the transmitters used in the measurements. The elevation angle could be readily varied by using the helicopter and also measurements could be made at chosen locations. Measurements were made at three frequencies, 893, 1550, and 2660 MHz which were transmitted continuously from the helicopter through drooping dipole antennas. The minimum spacing between antennas and to the edge of the groundplane on which they were mounted was two wavelengths and the resulting groundplane was approximately 1.2 by 2.0 meters. This was mounted between the skids of a Bell Jet Ranger and lowered in flight to just below the level of the skids, to avoid spurious results due to scatter from parts of the helicopter.

A van fitted with three receivers measured signal strengths as it was driven along selected roads with the helicopter flying parallel at constant relative height and elevation angle. The output level from each receiver was digitised at a 1.5 kHz rate under control of an IBM PC-AT compatible computer, and the results of a run were stored on a magnetic tape cartridge. Distance travelled was also recorded at the same time.

In October 1987 WARC-MOB allocated frequencies to the LMSS in the previous Aeronautical Mobile-Satellite Service (Route), AMSS(R), at 1545 to 1559 MHz and Australia will use these bands for LMSS. It was decided to continue the attenuation measurements at the three frequencies because the data obtained at 893 MHz will provide a point of comparison with equivalent North American data and 2660 MHz could be a possible future band for LMSS in Region 3.

RESULTS

This paper reports on data obtained on a typical double lane road close to the Telecom Research Laboratories in Melbourne, Australia. Messmate (stringybark) eucalyptus trees approximately 15 metres high lined the road with varying densities. Attenuation measurements were made on two different sections of road where the incidence of trees was 35% and 85%. All measurements were made with the helicopter

on the same of the road as the van. The raw data, scaled to decibels, was analysed by first searching for periods when there was clear line-of-sight between the helicopter and the van. These periods were recognised by the small peak-to-peak variation in signal strength and crosschecks were made that the results from the three frequencies coincided. These periods were used to adjust the data by removing the frequency independent helicopter - van distance variation, giving data scaled in decibels relative to line - of - sight.

Figure 1 shows the effect of elevation angle on the statistics for 35% tree density measured at 1550 MHz. The data are shown with a gaussian probability scale on the vertical axis and attenuation in positive decibels on the horizontal. Negative values of attenuation indicate signal strengths above line-of-sight due to multipath effects. With this scaling, straight line plots represent a log normal distribution for signal strength. From the data in Fig. 1 we note that at the 10% probability level the attenuation values are 5.7, 5.0, and 4.2 dB for 30, 45 and 60 degrees respectively. Figure 2 contains equivalent data for 85% tree density and the equivalent values for the 10% level are 10.8, 8.6, and 6.9 dB. Thus increasing elevation angle significantly reduces attenuation for equivalent percentage levels.

The distributions plotted in Figs. 3 and 4 show the increasing attenuation as the frequency increases. The axes and presentation in these Figures is identical to that in Figures 1 and 2 and data for 45 degrees elevation angle is shown. We note that at the 10% probability level the attenuations are 4.2, 5.0, and 7.8 dB for 897, 1550, and 2660 MHz respectively for 35% tree density and the corresponding attenuations for the 85% case are 6.6, 8.6, and 10.8 dB.

COMPARISON WITH OTHER DATA

There are obvious difficulties in making comparisons with other data which has most often been collected with somewhat different parameters and one purpose of these measurements is to assess the applicability of other data to Australia. Figure 5 compares cumulative distributions reported by Goldhirsh and Vogel (1987) obtained at 870 MHz using a helicopter in a very similar manner to that reported here. The data is for 45 degrees elevation angle and the percentage values categorising tree density is equivalent to that used here. The results for the distributions derived from the more densely wooded sections of road are in good agreement: at the 10% level, 6.9 dB vs 6.5 dB for Goldhirsh and Vogel. The agreement for 35% tree density is not as good: 4.5 dB reported here vs 2.7 dB at the 10% level.

Figure 6 compares results reported by the European Space Agency's PROSAT programme (Jongejans et al, 1986). These results are based on measurements made using the INMARSAT satellite in the frequency band 1530- 1545 MHz and are for rural areas in Belgium. The elevation angle is over 25 degrees but no information on tree density is given except for a photograph indicating it would be between 35% and 85%. If this visual assessment is correct there is general agreement between the two distributions with an attenuation value of 7.5 dB from the European data compared to 10.8 and 5.7 dB measured in Australia for the 85% and 35% cases respectively at the 10% probability level.

The attenuation statistics reported here are therefore generally consistent with other data with some evidence that Australian conditions produce higher attenuation values.

COMMENTS

Given the above data, a prime question is how these results should be treated in a system design. It is clearly uneconomic to provide a 10.8 dB margin to all mobile receivers so that a required performance objective will be achieved, for example, 90% of the time in areas with 85% tree density and an elevation angle of 30 degrees to the satellite. One possible alternative could be to determine an average margin based on relative areas of different vegetation regions for given elevation angles. To illustrate this point, consider the data shown in Table 1 which is based on data estimating the natural vegetation coverage for Australia without the effects of settlement. This data is used on the basis that current roadside vegetation may closely resemble the original undisturbed environment. Contained in Table 1 are the margins at the 10% level based on the measurements reported here. Given the broad nature of these areas and the wide variation in coverage densities the margins used may not be appropriate but are included here to illustrate the principle. The margins are most probably conservative because it is estimated that the major part of the areas considered contain tree heights and densities less than that for which the margins have been measured. This would require further study. From these figures an average margin of 5.4 dB is required, a much reduced value.

Table 1. Relative areas (%) of different vegetation types[a] and associated propagation margins (dB) for Australia

	Elevation angle (degrees)					
Tree Type	30-45		45-60		>60	
	%	Margin	%	Margin	%	Margin
1. Forest[b] Trees >10m cover 10-70%	4.6	10.8	14.7	8.6	3.4	6.9
2. Scrub[c] Trees and woody shrubs 1-10m cover 10-70%	19.7	5.7	12.2	5.0	1.5	4.2
3. Grasses[d] <1m	14.0	1.0	28.0	1.0	1.9	1.0

[a]Russell and Coupe (1984)
[b]Assumed to correspond to the 85% case
[c]Assumed to correspond to the 35% case
[d]A nominal margin is assumed

This average margin implies that the actual margin is adaptively allocated as required and the technical detail involved with such a scheme would need to be carefully studied. A more refined approach would use customer densities as the weighting function in the averaging process, rather than relative geographic area, but this approach is beyond the scope of this paper.

This type of argument provides information on where to focus future work: in Australia's case more attenuation statistics and geographic detail are required for the tree type areas 1 and 2 outlined in Table 1.

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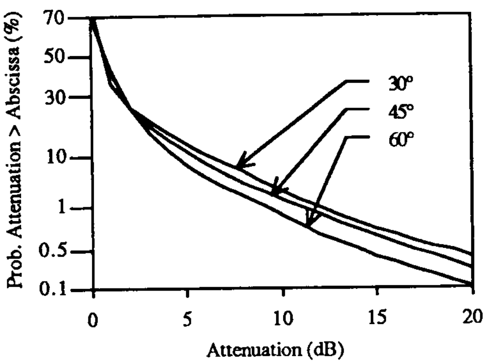

Fig. 1. Attenuation distributions for various elevation angles, 35% tree density and at 1550 MHz

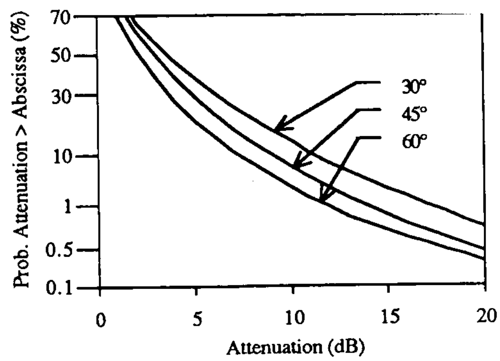

Fig. 2. Attenuation distributions for various elevation angles, 85% tree density and at 1550 MHz

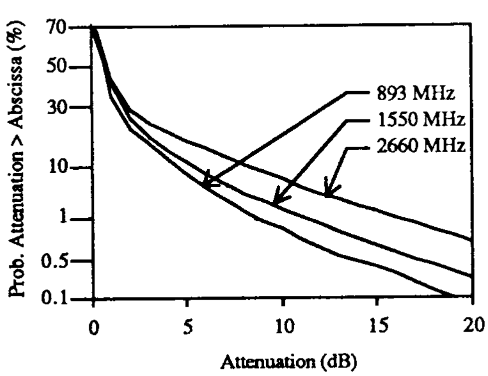

Fig. 3. Attenuation distributions for various frequencies, 35% tree density and at 45° elevation

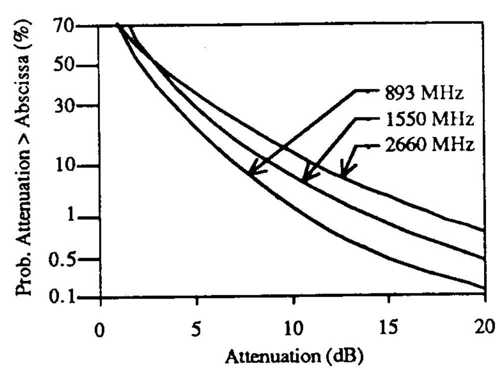

Fig. 4. Attenuation distributions for various frequencies, 85% tree density and at 45° elevation

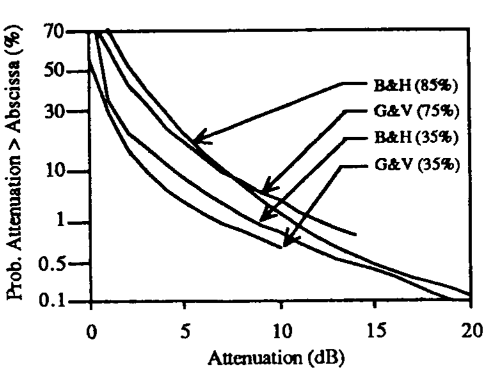

Fig. 5. Comparsion between attenuation distributions measured by Bundrock & Harvey and Goldhirsch & Vogel for 45° elevation angle, at UHF frequencies and various tree densities.

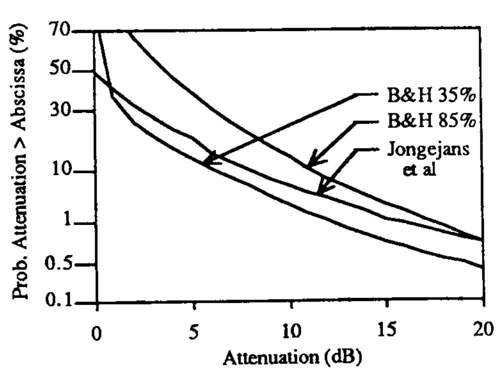

Fig. 6. Comparsion between attenuation distributions measured by Bundrock & Harvey and Jongejans et al for 30° elevation angle, at L-band and various tree densities.